METAL SEAL DESIGN:
HOW DOES A METAL SEAL WORK?

SEALING IS A SYSTEM

For metal seals, the design of the mating hardware is as critical as the seal design. Most traditional design standards related to polymer o-rings do not apply.

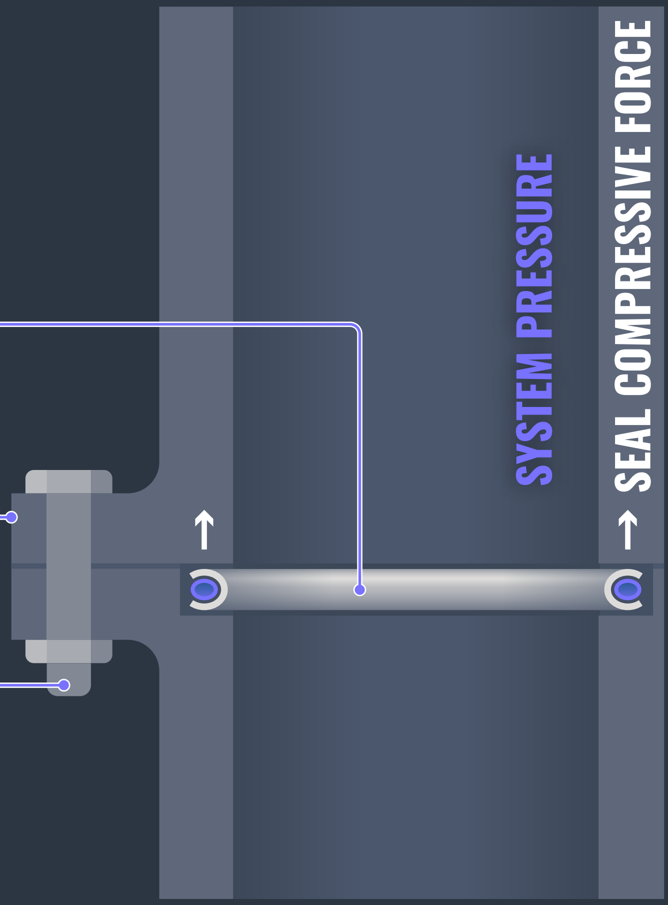
The bolting, materials, seal load and system pressure, and temperatures all combine to affect flange separation, which is the main consideration.

This resource will help designers by highlighting key areas to consider when improving system performance with metal seals.

BOLTED JOINTS

A bolted joint is an assembly that relies on each component to work properly. The performance and success of the bolted joint depends on the quality and design of each of these components. There are three major components of every bolted joint:

1) **SEAL / GASKET**
2) **FLANGES** (FLANGE DESIGN/GROOVE DIMENSIONS AND FINISH)
3) **BOLTS / FASTENERS**



The above components cannot be designed exclusively of each other. They must be considered together as a system during the design process. If any part of the bolted joint assembly does not perform properly, the joint as a whole will not perform to expectation and may leak.

SEAL DESIGN STARTS WITH LEAK RATE

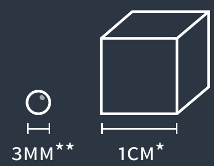
ONE WAY TO EXPRESS LEAK RATE

Below is a commonly used way to express leak rates. Understanding the performance your application requires is critical to selecting the correct seal design.

LEAK LEGEND	APPROX. LEAK RATES (PER METER OF CIRCUMFERENCE)	ACTUAL LEAK RATE IN SERVICE WILL DEPEND ON THE FOLLOWING:
Ultra-Helium	$\leq 1\times10^{-11}$ std.cc/sec He	**SEAL LOAD:** Wall Thickness or Spring Load
Helium	$\leq 1\times10^{-9}$ std.cc/sec He	**SURFACE FINISH:** Seal and Cavity
Bubble	$\leq 1\times10^{-4}$ std.cc/sec He	**SURFACE TREATMENT:** Coating/Plating/Jacket Material
Low-Bubble	≤ 25 co/sec @ 50 psig Nitrogen per inch of diameter	

EVERYTHING LEAKS

When asked about a desired leak rate, its common for designers to respond 'No leaks'. However, everything leaks...



VISUALIZATION OF STD CC TO SCALE

STD CC/SEC*	MBAR-L/SEC	TORR LITERS/SEC	TIME FOR ONE CC TO LEAK	TIME FOR ONE BUBBLE** TO LEAK
10^{-1}	1.01×10^{-1}	7.6×10^{-2}	10.0 seconds	0.25 seconds
10^{-2}	1.01×10^{-2}	7.6×10^{-3}	100.0 seconds	2.50 seconds
10^{-3}	1.01×10^{-3}	7.6×10^{-4}	16.7 minutes	25.00 seconds
10^{-4}	1.01×10^{-4}	7.6×10^{-5}	2.8 hours	4.00 minutes
10^{-5}	1.01×10^{-5}	7.6×10^{-6}	28.0 hours	40.00 minutes
10^{-6}	1.01×10^{-6}	7.6×10^{-7}	11.5 days	7.00 hours
10^{-7}	1.01×10^{-7}	7.6×10^{-8}	3.8 months	3.00 days
10^{-8}	1.01×10^{-8}	7.6×10^{-9}	3.2 years	1.00 month
10^{-9}	1.01×10^{-9}	7.6×10^{-10}	32.0 years	9.00 months
10^{-10}	1.01×10^{-10}	7.6×10^{-11}	320.0 years	8.00 years
10^{-11}	1.01×10^{-11}	7.6×10^{-12}	3200.0 years	80.00 years

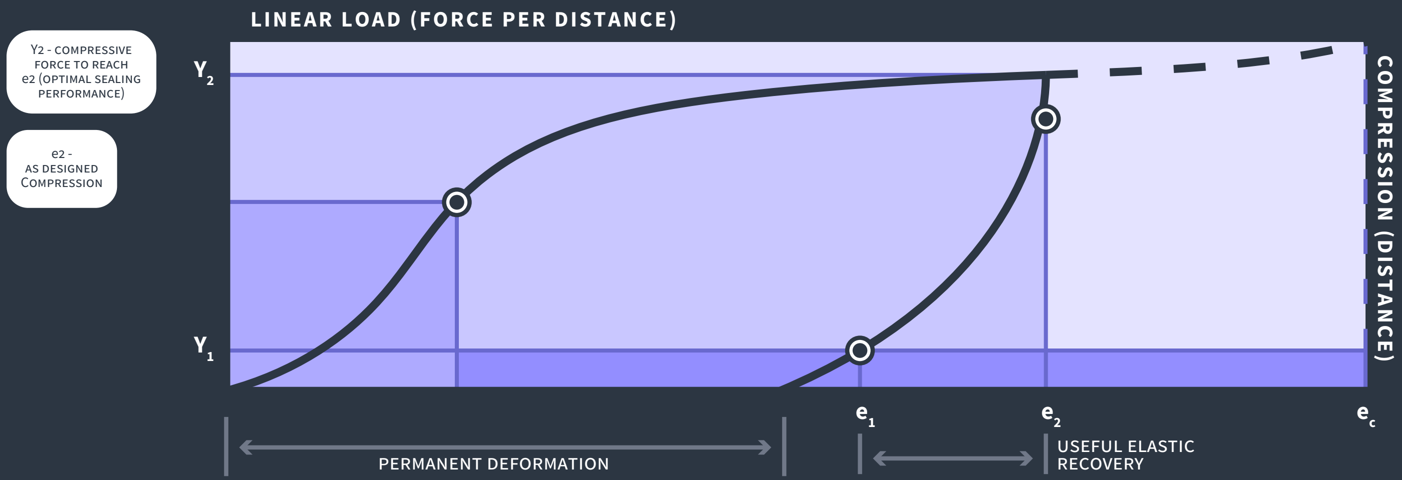
SEAL

COMPRESSION / ELASTICITY

Controlling compressive force is essential for proper metal seal performance. Enough force must be generated to overcome the yield strength of the seal but not so much as to over-compress the seal. Outside of clamping force generated by properly design bolting hardware, additional energy can be generated in two ways.

MECHANICAL ENERGY

Spring energized seals like the Helicoflex use a coiled spring to create additional compressive force in cases where a seal is used in a vacuum or high pressure differential environment



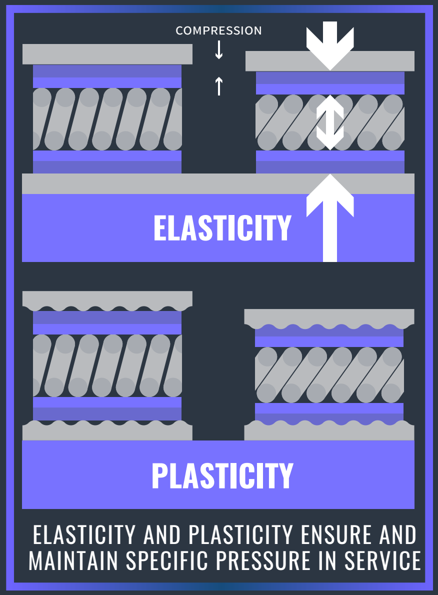
PRESSURE / PLASTICITY

Most metal seals create tight seals through a concept known as plastic deformation. This is accomplished by utilizing a soft outer coating, such as PTFE, gold or silver, and then applying a specific amount of force to deform the outer layer into the mating hardware as shown.

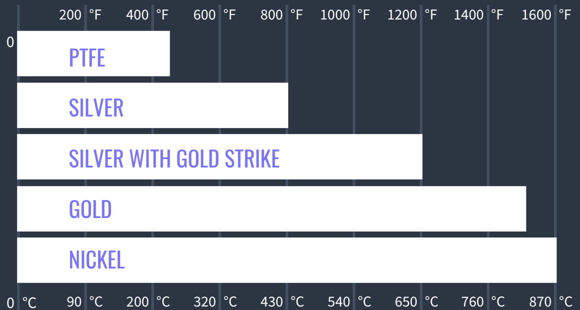
This is a typical load curve used to demonstrate specific values critical to a metal seal's optimal performance. These values are directly impacted by the sealing system and are central to proper seal design.

PASSIVE ENERGY

Self energized metal seal designs can utilize environmental pressures to improve leak rates



HERE ARE SOME IDEAL TEMPS BASED ON THE PLATING MATERIAL UTILIZED.



MAX RECOMMENDED OPERATING TEMPERATURE

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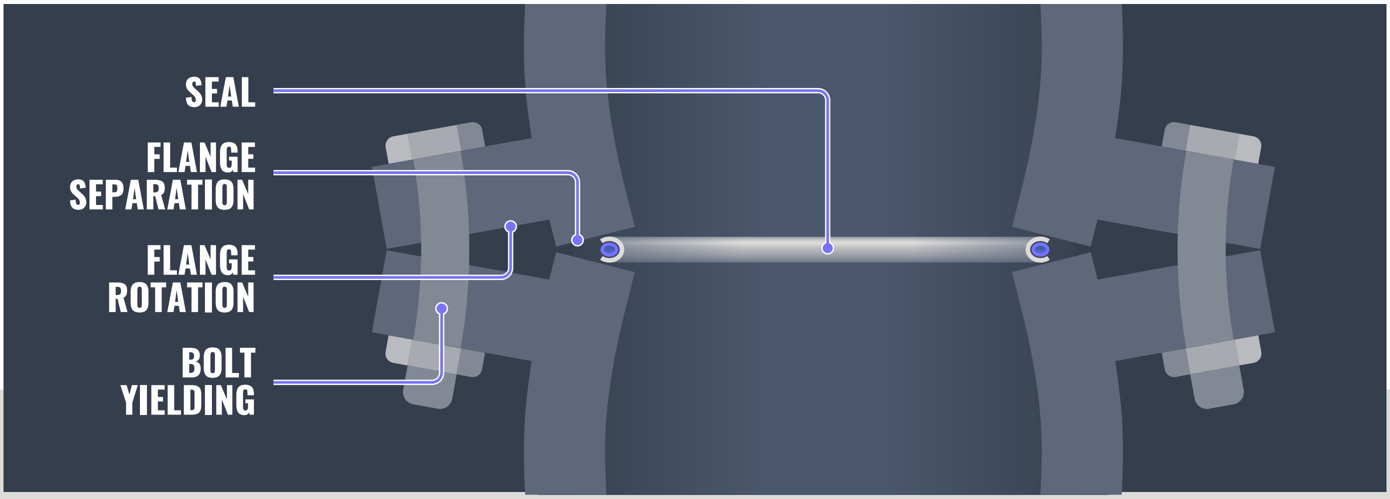
FLANGE

The chief consideration in flange design is to minimize flange separation. There are several factors that must be considered during this process. They are bolting, materials, seal load & system pressure, and temperature. As these factors reach extreme levels, flange separation increases, and sealing becomes more difficult.

Ideally, this value should be provided in order to begin seal design.

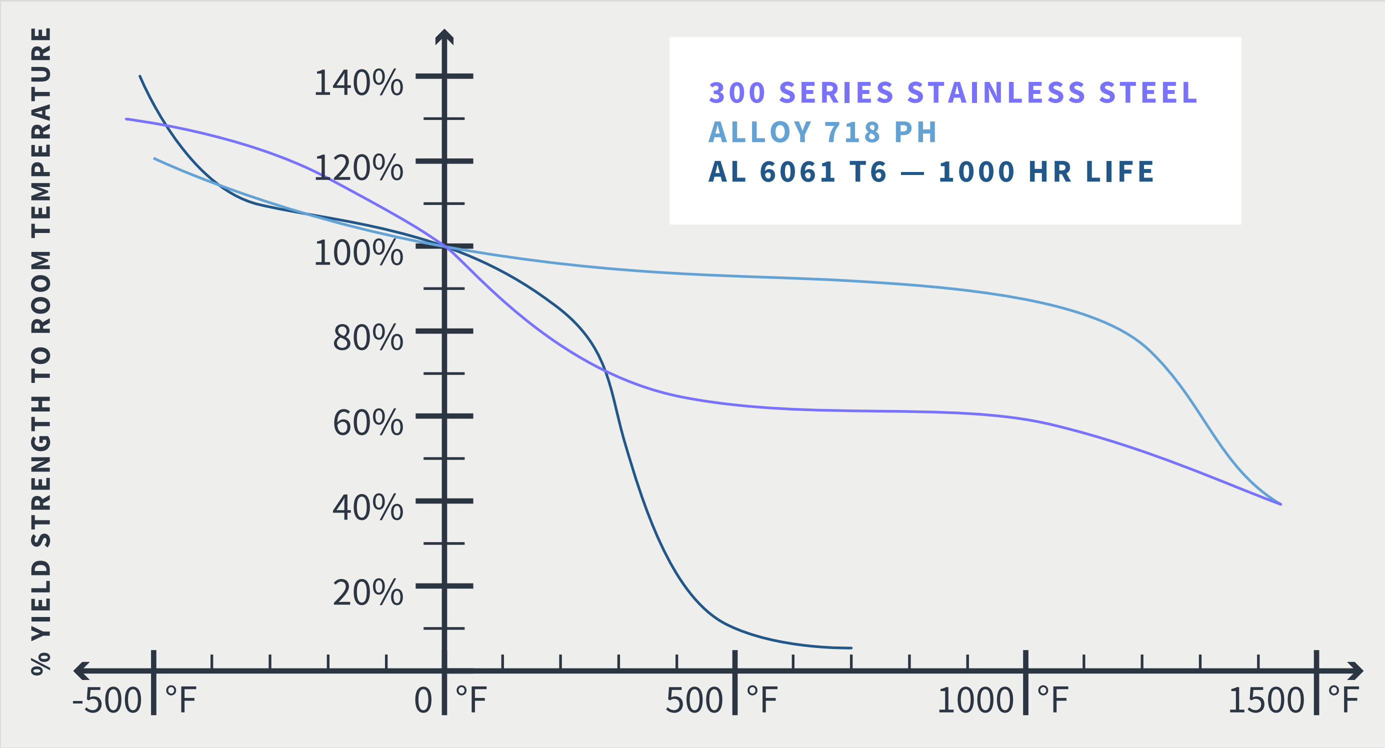


TEMP / PRESSURE

Temp/Pressure are the two most impactful factors that affect flange separation. They are also the least likely to be able to modified.

OPTIONS TO MINIMIZE FLANGE SEPARATION:

- Increase Bolting
- Change Flange Material
- Increase Flange Thickness



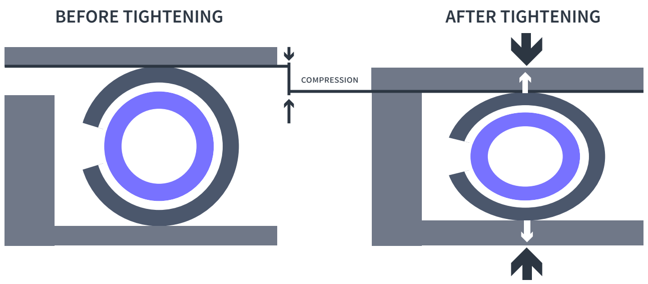
GROOVE

A rectangular groove is almost always the best choice for a metal seal.

Other considerations are the dimensional tolerances, flatness, surface finish values and the lay of the surface finish.

WHY A GROOVE?

Metal to metal sealing shown below. Ensures that the seal is loaded evenly and ensures an optimal value for seal compression and performance. In cases where a groove is not possible a metal limiter may be substituted to control seal compression. Whether a design uses a groove or a limiter, optimal seal compression can be confirmed through metal-to-metal contact of the flanges.



SMOOTHNESS

Surface Finish is the most important consideration when designing the groove to ensure a good seal. That's because the proper finish and lay will eliminate possible leak paths, which is critical to creating a high performing seal.

The directional lay of a finished surface refers to the direction of the maching or polishing marks. A fine surface finish that is perpendicular the direction of pressure is recommended.

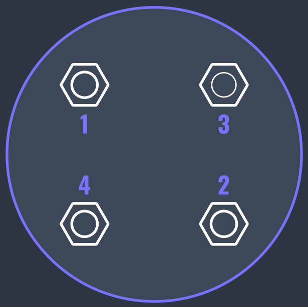
POOR FLANGE FINISH - RADIAL MARKS

GOOD FLANGE FINISH - CONCENTRIC MARKS

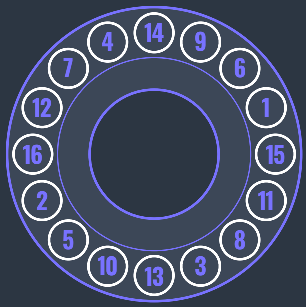
BOLTING

CONFIGURATIONS & CLAMPING FORCE

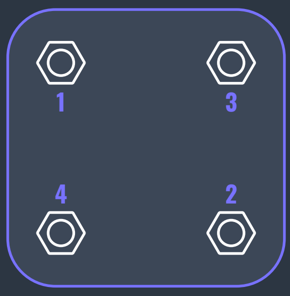
When using bolts to fasten the sealing joint, the bolts must be of suitable strength and quantity to compress the seal and withstand the maximum hydrostatic load. Additionally, the bolts and flanges must be robust enough to prevent warpage, distortion, or separation during service. All service factors must be considered, such as thermal stresses, differential expansion, external loads, and vibration.



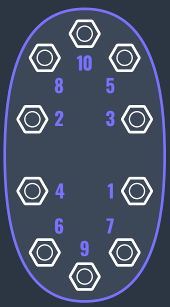
CIRCULAR FOUR-BOLT



CIRCULAR MULTIBOLT



SQUARE FOUR-BOLT



NONCIRCULAR MULTIBOLT

To discuss your specific sealing design with a metal seal expert contact Technetics at:

technetics.com/technetics-products/metal-seals